Long-Term Effect of Cropping Systems and Organo - Mineral Fertilization on Production and Soil Quality in the North-Eastern Romania

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1. Abstract

The experiments was carried out at the Agricultural Research Station of Podu-Iloaiei, Iasi County, on a 14% slope land, with Cambic Chernozem soil-type, which has a loam-clayey texture (423 g clay, 315 g loam and 262 g sand), a neuter to weakly acid reaction and a mean nutrient supply. The average yield increases, obtained in maize during 1997-2006, were between 10 and 28 % (468 – 1276 kg/ha), due to crop rotation, and between 32 and 92 % (1075 – 3107 kg/ha), due to applied fertilizer rates. The 40-year use of the rotation peas – wheat – maize – sunflower + reserve field, cultivated with perennial grasses and legumes, determined a high yield increase, as compared with continuous cropping, of 39% (963 kg/ha) in wheat and 28% (1276 kg/ha) in maize. On slope lands, the high mineral rate fertilization ($N_{140}P_{100}$) has determined, in the last 11 years, an average yield increase of 113% (1874 kg/ha) in wheat and 90% (3032 kg/ha) in maize, as compared with the unfertilized control. Applying mean rates of mineral fertilizers ($N_{60}P_{40}$) with 30 t/ha manure has resulted in getting average yield increases comprised between 2123 kg/ha in wheat and 3107 kg/ha in maize, as compared with the unfertilized variant. The 40-year use of 3 and 4 year crop rotations has determined the increase in the mass of total carbon and mobile phosphorus from soil by 13% (2.2 C g/kg) and, respectively, 40% (15 P-AL mg/kg), in comparison with maize continuous cropping. The mass of total carbon in the Cambic Chernozem from the Moldavian Plain has registered significant increases at higher rates than $N_{140}P_{100}$, in case of organo - mineral fertilization and in 4-year crop rotation +reserve field, cultivated with perennial grasses and legumes. In maize continuous cropping and wheat-maize rotation, increases with very significant values of the carbon content were found only in organo - mineral fertilization, in 4-year crop rotation + reserve field, cultivated with perennial legumes, and in case of $N_{140}P_{100}$ fertilization.

2. Introduction

In the last period, the investigations conducted in different countries have followed the influence of improving technological elements on fertilization, soil tillage and crop rotations with legumes and perennial grasses, which determine the increase in the content of organic carbon from soil and the reduction of N_2O emissions. The N_2O emissions from soil increase linearly with the amount of mineral nitrogen applied by fertilization (0.0119 kg N_2O-N kg N^{-1}). The application of manure determines the diminution in nitrogen protoxide emissions (0.99 kg N_2O-N ha−1 year^{-1}), compared with the application of liquid manure (2.83 kg N_2O-N ha^{-1} year^{-1}) or mineral fertilization (2.82 kg N_2O-N ha^{-1} year^{-1}) (Gregorich (2005).

The calculation done on the basis of the results obtained in two long-term trials (Bad Lauchstädt Static Fertilizer Experiment in Germany and The Broadbalk Wheat Experiment) has shown that the annual soil amendment with 10 t/ha manure may result in increasing the carbon reserve from soil by 4.8%, in 90 years, at the depth of 30 cm (Powlson et al. (1998). The regeneration of 30% of forests, according to the requirements proposed for the year 2010, may determine, over 100 years, the increase by 12.4% in the carbon reserve from the European soils.

The investigations conducted in the stationary experiments from Bad Lauchstädt have shown that in the crop rotation sugar beet – spring barley – potato – winter wheat, the mineral fertilization has determined the increase in the content of organic carbon from soil by 0.66%. The fertilization with 20 t/ha manure + mineral fertilizers had the same effect on the content of organic carbon, at the rate of 30 t/ha manure (Körschens (1996).

The investigations carried out by Liu et al., 2006, in NE Colorado, have shown that N_2O emissions diminished very much by nitrogen incorporation into soil at the depth of 10 -15 cm (Liu et al., 2006). The use of legumes for soil protection against erosion has resulted in fixing 105 kg from the atmospheric nitrogen and annual increasing of the carbon content from soil by 1055 kg, which is twice higher than the accumulation in the no-till system. (Farahbakhshazada (2008).

From the investigations conducted at Baden-Württemberg, Germany, on a Gleyic Cambisol, it was found that in the wheat crop, fertilized with $N_{140}P_{30}K_{60}$, straw and root biomass have determined the increase in the content of mineralized carbon by 12.0 and 9.44%, respectively (Marhan, (2008). Many investigations conducted in different countries have shown that applying low rates of mineral fertilizers with nitrogen, phosphorus and potassium in wheat and maize continuous cropping and wheat-maize rotation has determined the diminution in the content of organic matter from soil. The diminution in the content of organic carbon from soil, due to mineral fertilization, was found in loam -sandy fields from Nashua, USA, where lower than 180 kg nitrogen/ha were applied in maize-soybean rotation (Russell, (2006) and in clay loam soils from Rothamsted, England, where lower rates than $N_{192}P_{35}K_{90}Mg_{35}$ were applied (Blair et al., (2006). Investigations conducted by Allmaras R. R., 2006 on loam-sandy soils from Rosemount, Minnesota, have shown that applying rates of 200 kg nitrogen as ammonium sulfate [$(NH_4)_2$ SO_4]), contributed to the increase in the amount of organic residues from soil and determined the increase in the organic carbon content by 20% against the unfertilized control (Allmaras (2006).

3. Methods

Since 1968, the investigations conducted at the Agricultural Research and Development Station of Podu-Iloaiei has followed the influence of different crop structures, rotations and fertilizers on crop yield and soil fertility. These experiments was carried out on a 14% slope field, on a Cambic Chernozem with clay loam texture (423 g clay, 315 g loam and 262 g sand), a neuter to weakly acid reaction and a mean nutrients supply.

The soil on which physical and chemical analyses were done, was sampled at the end of plant growing period. Soil response was determined in water suspension by potentiometrical means with glass electrode. The content of organic carbon was determined by the Walkley-Black method, modified by Gogoasa, and multiplied by 1.724; the content in mobile phosphorus from soil was determined by Egner-Riechm Domingo method, in solution of ammonium acetate-lactate (AL), and potassium was measured in the same extract of acetate-lactate (AL) at flame photometer.

4. Results

The rainfall amounts registered during 1997-2007 (January-June) were greater, compared with the average of the last 79 years, with values between 20.4 and 140.2 mm in five years, and lower by 38.3-119.0 mm, in six years. The rainfall amounts registered in the last 11 years, during September-November, have resulted in normal conditions for wheat growing in six years, and were lower, compared to the multiannual mean, in five years. During 1997-2007, the climatic conditions were favorable to plant growing and development, for five years in wheat and six years in maize. The mean annual rainfall amounts, registered in the last 11 years, were higher, with values comprised between 96.2 and 182.4 mm, compared to the multiannual mean on 80 years (544 mm) in four years, and lower by 25.3-100.1 mm in four years.

Between January and September, the average rainfall amounts, registered in the last 80 years, were of 424.9 mm. During 1997-2007, drought has affected maize crop in five years, when differences were between 38.0 (1997) and 94.5 mm (2003), as compared with the multiannual mean.

The crop rotation is also important under conditions of an intensive technology, being the main measure for soil protection, crop phytosanitary protection and efficient capitalization of all technological factors. Crop rotations with annual and perennial grasses and legumes have increased the biodiversity of agro-ecosystems, diminished the quantity of nitrogen-based fertilizers, contributed to the increase in soil fertility and diversified the options of farming management.

On the Cambic Chernozem from the Moldavian Plain, growing wheat in 3 and 4-year crop rotations with annual and perennial legumes has determined yield increases of 34 – 39 % (832 – 963 kg/ha) as compared with maize continuous cropping. Maize growing in 4-year rotation (peas-wheat-maize-sunflower) + ameliorative field, cultivated with perennial grasses and legumes, has determined yield increases of 18 % and 808 kg/ha, respectively, compared with wheat-maize rotation (which is the most commonly used rotation by farmers) (Table 1).

Applying high fertilizer rates ($N_{140}P_{100}$) in wheat has determined, in the last 11 years, an average yield increase of 113 % (1874 kg/ha),while the use of low mineral fertilizer rates ($N_{60}P_{40}$), together with 30 t/ha manure, resulted in getting an yield increase of 128% (2123 kg/ha) (Table 2).

The average yield increases, obtained in maize during 1997-2006, were between 10 and 28 % (468 – 1276 kg/ha), due to crop rotation, and between 32 and 92 % (1075 – 3107 kg/ha), due to applied fertilizer rates (Tables 1, 2). Applying mean rates of mineral fertilizers ($N_{60}P_{40}$) with 30 t/ha manure has resulted in getting average yield increases comprised between 2123 kg/ha in wheat and 3107 kg/ha in maize, as compared with the unfertilized variant.

The analyses carried out on the evolution of soil response, after 40 years of experiencing, have shown that the significant diminution in the pH value was found at higher rates than 100 kg N/ha (Table 3). Applying high nitrogen rates as ammonium nitrate (100-140 kg/ha) has determined the pH diminution (0-20 cm) until 6.0-5.6 in wheat-maize rotation and until 6.8-6.5 in peas- wheat-maize-sunflower + reserve field, cultivated with perennial grasses and legumes. The lowest pH value was finding in maize continuous cropping and wheat-maize rotation; this can be explained by high nutrient uptake of these crop rotations and unfavorable conditions in which the processes of nitrification and crop residue decay developed.

The results obtained showed that the 5-year crop rotation with perennial grasses and legumes has limited the pH diminution (compared to the wheat-maize crop rotation), even under the long-term use of high nitrogen fertilizer rates. After 40 years of experiencing in a 4-year crop rotation + reserve field, cultivated with perennial grasses and legumes, soil response was within the limits of weakly acid (6.4-6.8), even when using high fertilizer rates (100-140 kg/ha) with acidifying effect, as ammonium nitrate. In maize continuous cropping and wheat-maize rotation, although a great amount of crop residues accumulated into soil, this supply of organic matter did not improve soil response.

The humus content from soil, in case of the mineral fertilization has increased (in comparison with the control), by significant values only at high fertilizer rates ($N_{140}P_{100}$) and in 3 and 4-year crop rotations with annual and perennial legumes (Tables 3, 4). As compared with the 4-year crop rotation, in the wheat - maize rotation with ameliorating plants (annual and perennial legumes and perennial grasses), the average humus content from soil has decreased from 3.22 to 2.88 %, and the content in mobile phosphorus diminished from 52 to 37 ppm (Tables 4). In maize continuous cropping and wheat-maize rotation, applying mineral fertilizer rates of $N_{140}P_{100}$, did not result in significant differences of the humus content from soil (in comparison with the unfertilized control); this demonstrated that in these crop rotations, maintaining a positive balance of the organic matter was done only by organo-mineral fertilization. In maize continuous cropping and wheat-maize rotation, maintaining a good supply in mobile phosphorus (37-72 ppm phosphorus) was done by the annual application of rates of $N_{100}P_{80}$. The 40-year use of 3 and 4-year crop rotations, which included ameliorating plants of perennial grasses and legumes in the crop structure, has determined a good degree of the mobile phosphorus supply in soil at the rate of $N_{60}P_{40}$.

The analyses on the content of mobile potassium from soil have shown that in all the tested crop rotations, the supply condition was good (133-200 mg/kg) in case of mineral fertilization and very good (over 200 mg/kg) in case of fertilization with $N_{60}P_{40}$+30 t/ha manure. The supply with mobile potassium in the wheat-maize rotation was lower, because of the high potassium consumption by these crops and of the unfavorable conditions of soil structure, which influence the supply with mobile potassium from soil reserve.

The mass of total carbon from Cambic Chernozem in the Moldavian Plain has registered significant increases at higher than $N_{140}P_{100}$ rates, in case of organo-mineral fertilization and in 4-year crop rotation, which included ameliorative plants of perennial grasses and legumes (Table 5). In maize continuous cropping and wheat-maize rotation, very significant values of the carbon content was found only in the organo-mineral fertilization, in 4-year crop rotation + reserve field, cultivated with perennial legumes and in $N_{140}P_{100}$ fertilization.

Table 1 Influence of rotation on wheat and maize yield during 1997 – 2007

Crop rotation	**Wheat yield**		**Dif.**	**Sign.**	**Maize Yield**		**Dif.**	**Sign.**
	kg/ha	**%**	**kg/ha**		kg/ha	%	**kg/ha**	
Continuous cropping	2454	100	0		4586	100		
Wheat – maize	2511	102	57		5054	110	468	x
Peas –wheat-maize	3286	134	832	xxx	5632	123	1046	xxx
Peas –wheat-maize –sunflower + reserve field cultivated with legumes and perennial grasses	3417	139	963	xxx	5862	128	1276	xxx
LSD 5 %			204	kg/ha			460	kg/ha
LSD 1 %			375	kg/ha			632	kg/ha
LSD 0.1 %			587	kg/ha			844	kg/ha

Table 2 Influence of fertilizers on wheat and maize yield during 1997 – 2007

Crop rotation	**Wheat yield**		**Dif.**	**Sign.**	**Maize Yield**		**Dif.**	**Sign.**
	kg/ha	**%**	**kg/ha**		kg/ha	%	**kg/ha**	
N_0P_0	1662	100	0		3368	100	0	
$N_{60}P_{40}$	2492	150	830	***	4443	132	1075	***
$N_{100}P_{80}$	3110	187	1448	***	5733	170	2365	***
$N_{140}P_{100}$	3536	213	1874	***	6400	190	3032	***
$N_{60}P_{40}$+30 t/ha manure	3785	228	2123	***	6475	192	3107	***

LSD 5 %			204	kg/ha			552	kg/ha
LSD 1 %			375	kg/ha			740	kg/ha
LSD 0.1 %			587	kg/ha			976	kg/ha

Table 3 Change of main soil agrochemical indices as influenced by fertilizers, after 40 years of experiments

Fertilizer rate	pH, H_2O	P-AL, mg/kg	K-AL, mg/kg	Humus, %
N_0P_0	7.1	13	206	2.84
$N_{60}P_{40}$	6.9	33	180	2.89
$N_{100}P_{80}$	6.4	46	184	2.97
$N_{140}P_{100}$	5.9	61	196	3.12
$N_{60}P_{40}$+30 t/ha manure	7.0	68	286	3.42
LSD 5%	0.52	4.3	16	0.26
LSD 1%	0.82	5.7	23	0.39
LSD 0.1%	1.19	7.5	33	0.54

5. Conclusions

The 40-year use of the rotation peas – wheat – maize – sunflower + reserve field, cultivated with perennial grasses and legumes, determined a high yield increase, as compared with continuous cropping, of 39% (963 kg/ha) in wheat and 28% (1276 kg/ha) in maize. On slope lands, the high mineral rate fertilization ($N_{140}P_{100}$) has determined, in the last 11 years, an average yield increase of 113% (1874 kg/ha) in wheat and 90% (3032 kg/ha) in maize, as compared with the unfertilized control.

The mean rate mineral fertilization ($N_{60}P_{40}$), together with 30 t/ha manure, has determined the yield increase of 128% (2123 kg/ha) in wheat and 92% (3107 kg/ha) in maize, as compared with the unfertilized control.

Applying the rate of $N_{140}P_{100}$ for 39 years has determined the pH decrease until the limit of moderately acid interval (5.1-5.8) in wheat continuous cropping and wheat-maize rotation, and was maintained within the weakly acid interval (5.9-6.8) in 3 and 4 –year crop rotations with annual and perennial legumes.

The 40-year use of 3 and 4- year crop rotations has determined the increase in the mass of total carbon and mobile phosphorus from soil by 13% (2.2 C g/kg) and, respectively, 40% (15 P-AL mg/kg), in comparison with maize continuous cropping.

Table 4 Change of main soil agrochemical indices as influenced by crop rotation, after 40 years of experiments

Crop rotation	pH, H_2O	P-AL, mg/kg	K-AL, mg/kg	Humus, %
Maize continuous cropping	5.9	37	186	2.82
Wheat continuous cropping	6.6	42	213	2.99
Wheat – maize	6.2	37	195	2.88
Peas –wheat-maize	6.7	46	222	3.10
Peas –wheat-maize –sunflower + reserve field cultivated with legumes and perennial grasses	6.9	52	212	3.22
LSD 5%	0.43	3.8	14	0.22
LSD 1%	0.69	5.1	20	0.33
LSD 0.1%	1.02	6.7	28	0.47

Table 5 Influence of long-term fertilization and crop rotation on mass of total carbon from soil (C, g/kg)

Treatment	*Mcc	Wcc	WM	PWM	PWMS+G	Average	Dif.	Signif.
N_0P_0	15.0	15.9	15.2	16.5	16.8	15.9	0	
$N_{60}P_{40}$	15.5	15.7	14.8	16.9	17.1	16.0	0.1	
$N_{100}P_{80}$	15.8	16.4	16.2	17.3	18.2	16.8	0.9	
$N_{140}P_{100}$	16.8	17.2	17.0	18.5	19.7	17.8	1.9	x
$N_{60}P_{40}$+30 t/ha manure	19.0	19.4	19.0	20.1	21.4	19.8	3.9	xxx
Average crop rotation	16.4	16.9	16.4	17.9	18.6	17.3		
Difference	0	0.5	0.0	1.5^{x}	2.2^{xx}			
	Crop rotation	Fertilizer	Interaction					
LSD 5%	1.4	1.5	1.2	g/kg				

LSD 1%	1.8	2.1	1.6	g/kg				
LSD 0.1%	2.4	2.7	2.1	g/kg				

*Mcc= Maize continuous cropping, Wcc= Wheat continuous cropping, WM= Wheat-maize rotation, PWM= Peas –wheat-maize rotation, PWMS+G= Peas–wheat-maize –sunflower + reserve field, cultivated with legumes and perennial grasses.

6. References

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